

How asters find their center

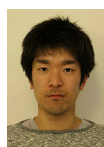
Researchers describe how microtubule asters move to the center of eggs after fertilization.

Microtubule asters—radial arrays of microtubules emanating from centrosomes—organize many cellular processes, including cell polarity and division. To perform their various functions, however, asters must move themselves to specific locations in the cell, using either the pushing forces of microtubule polymerization, or the pulling forces generated by microtubule-based motors. But how do asters “know” which way to move? Tanimoto et al. describe how the asters associated with sperm pronuclei guide themselves to the center of sea urchin eggs after fertilization (1).

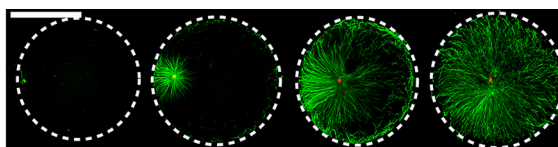
Sperm asters initially assemble at the egg periphery and must find their way to the center of the cell within minutes, a major challenge because eggs are so much larger than ordinary cells. The process of sperm aster centration has captivated cell biologists for over 90 years (2), yet little is known about the mechanisms that control the speed and direction of aster movement. “We wanted to revisit this classical problem using more modern techniques,” explains Nicolas Minc, from the Institut Jacques Monod in Paris, France.

Together with his postdoc, Hirokazu Tanimoto, and his collaborator, Akatsuki Kimura, from the National Institute of Genetics in Mishima, Japan, Minc tracked the three-dimensional movements of sperm asters inside sea urchin eggs, which have a diameter of $\sim 100\ \mu\text{m}$ (1). A few minutes after entering the egg, asters moved directly toward the center at a constant speed of $\sim 5\ \mu\text{m}/\text{min}$, only slowing down as they neared their destination. “The directional persistence was really striking,” says Minc.

Drug treatments revealed that aster migration depended on the microtubules themselves and the minus-end-directed motor dynein. To determine whether asters were moved by pushing or pulling forces, Tanimoto et al. used laser ablation to cut the microtubules on one side.



FOCAL POINT



PHOTOS COURTESY OF THE AUTHORS

(Left to right) Hirokazu Tanimoto, Akatsuki Kimura, and Nicolas Minc investigate how the microtubule asters associated with sperm pronuclei rapidly move to the center of sea urchin eggs after fertilization. The researchers find that asters are pulled to the cell center by dynein-dependent pulling forces. However, as shown in the time-dependent series of immunofluorescence images, asters start moving before microtubules (green) reach the far side of the egg, indicating that dynein pulls from the cytoplasm rather than from the cortex. Aster movement is directed to the center because centrally oriented microtubules grow longer, and can therefore recruit more dynein molecules. The speed of aster movement, however, remains constant and is largely determined by aster growth rate.

The damaged asters moved away from the cut side, indicating that they were being pulled by forces exerted on the remaining, intact, microtubules, and that similar pulling forces are responsible for moving the asters toward the egg center.

Dynein is generally thought to pull on asters from the cell cortex, where it can remain anchored as it walks toward the minus end of microtubules. But Tanimoto et al. found that, at least in sea urchin eggs, dynein pulls on asters from the cytoplasm. “The centration movement starts well before any astral microtubules reach the far side of the egg,” Minc says, “suggesting that microtubules don’t need to contact the cortex in order to exert pulling forces.”

How could dynein in the cytoplasm pull asters directly toward the cell center? One possibility is the length-dependent pulling hypothesis (3), which proposes that, because microtubules pointing toward the cell center can grow longer than microtubules pointing back toward the sperm’s entry site, they can recruit more dynein molecules and therefore generate more force. Computer simulations suggested that, even if eggs weren’t symmetrical spheres, length-dependent pulling forces would be capable of centering asters, albeit via a series of turns rather than by a direct path.

Accordingly, when the researchers manipulated the shape of sea urchin eggs by forcing them into rectangular wells, sperm asters moved to the cell center exactly as their simulations predicted. “It demonstrates that length-dependent pulling forces drive centration,” Minc says. “Moreover, it shows that asters can probe their local geometry to control their movement.”

One problem, however, is that asters increase in size almost 20-fold as they move toward the center of the egg. One might expect, therefore, that instead of moving at a constant speed, asters would accelerate as their microtubules grew and recruited more dynein molecules. But Tanimoto et al. found that aster speed is dictated by the growth rate of astral microtubules, rather than by the amount of dynein-dependent forces.

The next question, says Minc, is to determine how dynein is able to pull on asters from the cytoplasm. One possibility is that the motor is anchored to cytoplasmic vesicles or other organelles.

“Asters can probe their local geometry to control their movement.”

1. Tanimoto, H., et al. 2016. *J. Cell Biol.* <http://dx.doi.org/10.1083/jcb.201510064>
2. Wilson, E.B. 1925. *The Cell in Development and Heredity*. Third edition. The Macmillan Company, New York. 1232 pp.
3. Hamaguchi, M.S., and Y. Hiramoto. 1986. *Dev. Growth Differ.* 28:143–156.